

# Flash Drought over the United States

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# Motivation

Flash drought: a sudden onset of high temperatures and decreases of soil moisture (SM).

Based on physical mechanisms , we can separate into two types:

1. Type 1 : high  $T_{surf}$  => increases of ET (Evapotranspiration) => decreases of SM . What about precipitation??

ref: (Otkins et al 2012, Anderson et al 2012, Hunt et al. (2008))

2. Type 2 : starts from the lack of rain in spring. The atmospheric circulation and CIN (Convective Inhibition Energy) enhance the dry conditions → increases of  $T_{surf}$

In this case, ET decreases.

If there are no P deficits, will there be heat waves?

ref:Yang 2013, Myoung and Nielsen-Gammon 2012

# Questions?

- Why do we have two types of flash drought?
- Does flash droughts have preferred region to occur?
- What are local physical mechanisms responsible for flash drought?

# Data –

## Pentad data:

- **Observations:** surface temperature (Tsurf) , Precipitation (UW)
- **Surface variables:** total soil moisture, (SM) and ET from the NCEP NLDAS Noah and UW VIC pentad outputs from 1979-2011
- UW NLDAS VIC from 1950-2011
- **Atmospheric conditions:** CDAS from 1950-2011
- **Monthly mean SST:** ERSSTs
- Data period: April to September (Total 36 pentads/yr)

# Frequency of occurrence

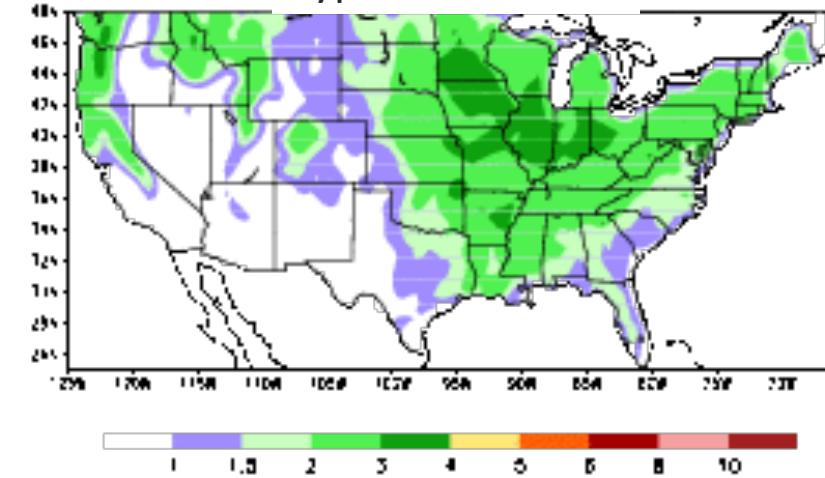
## Select events

For each pentad and each grid point, we select drought events using criteria

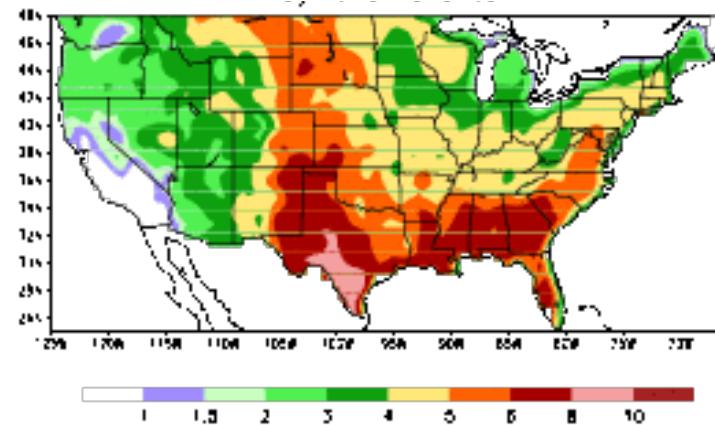
- For both types:
- $T_{surf} > 0.8 \text{ std dev}$  -- high temp
- $SM(t) - SM(t-1) < 0$  -- drop of SM
- $SM < 0$  --- drought
- type 1  $ET > 0.075 \text{ mm/day}$  ; type 2  $ET < -0.075 \text{ mm/day}$
- Process Noah and VIC separately, then take average
- Frequency of occurrence = total pentads selected/ record

# Frequency of occurrence

Type 1

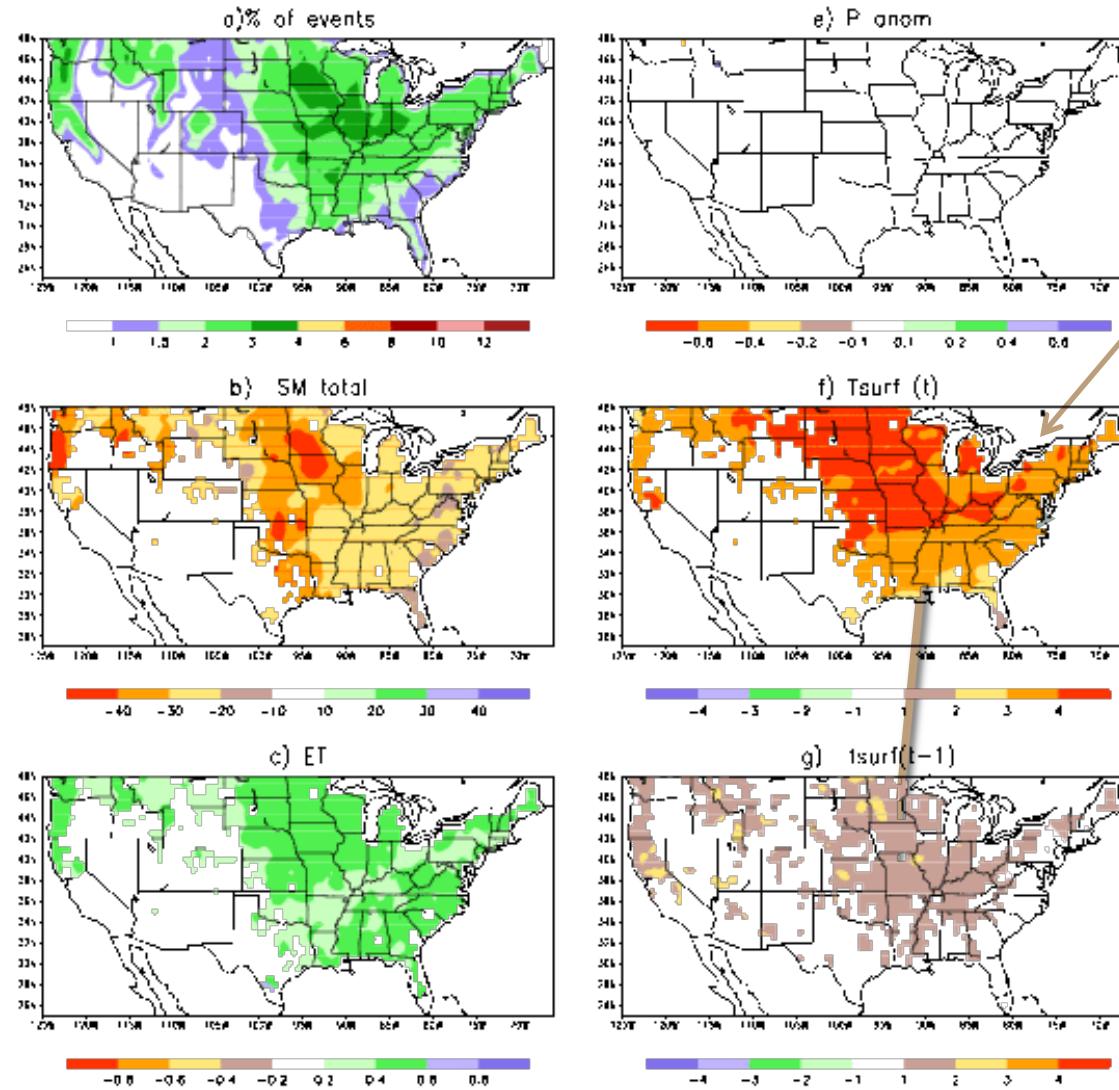


TYPE 2

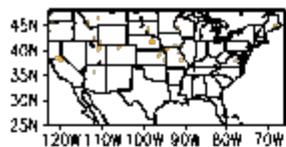
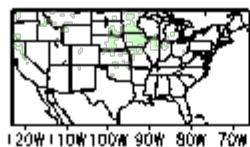
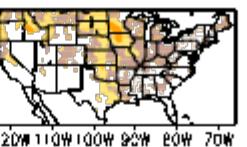
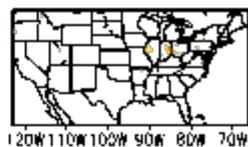


1. Only about 4-5% of total record
2. Occur in the eastern U.S. with maxima over the North Central and the Ohio Basin
1. More common about 5-8% of total record
2. With maxima over the Southern Plains and the Gulf states
3. There are more type 2 events in the area that the type 1 is more likely to occur.

# Composite of type 1 events

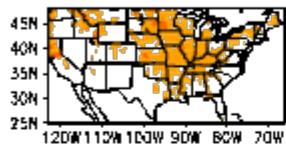


1.  $ET > 0$ .
2.  $T_{surf}$  increases 2-3 C within 5 days (rapid onset of heat waves)
3.  $SM < 0$ .
4. No  $P$  anomalies

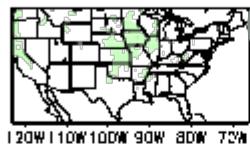
Tsurf  
a)-2 pentET  
f)-2 penttotal SM  
k)-2 pentP  
p)-2 pent

## Evolution of type 1 flash drought

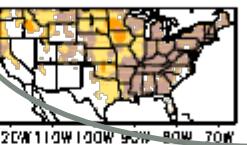
b)-1 pent



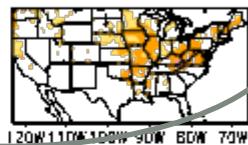
g)-1 pent



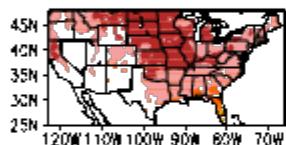
i)-1 pent



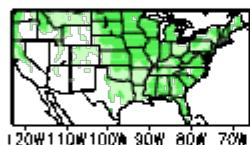
q)-1 pent



c) onset



h) onset

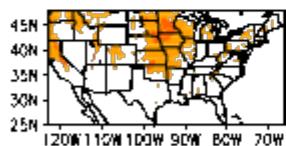


→ Drop of SM

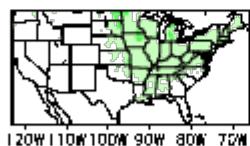
r) onset



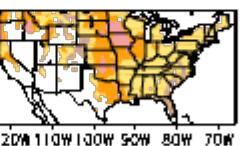
d)+1 pent



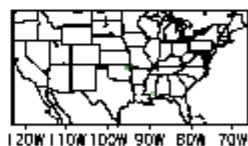
i)+1 pent



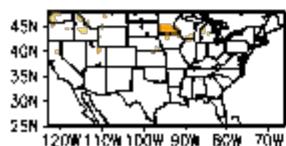
n)+1 pent



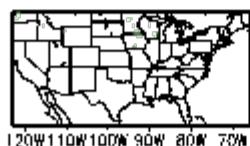
s)+1 pent



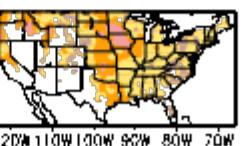
e)+2 pent



j)+2 pent



o)+2 pent



t)+2 pent



- At pentad -1, Tsurf increases. Heat waves last for 3 pentads only
- Good correspondence btw Tsurf=> ET => large drop of SM
- SM anomalies persist and cause damages

Q? Does P do anything?

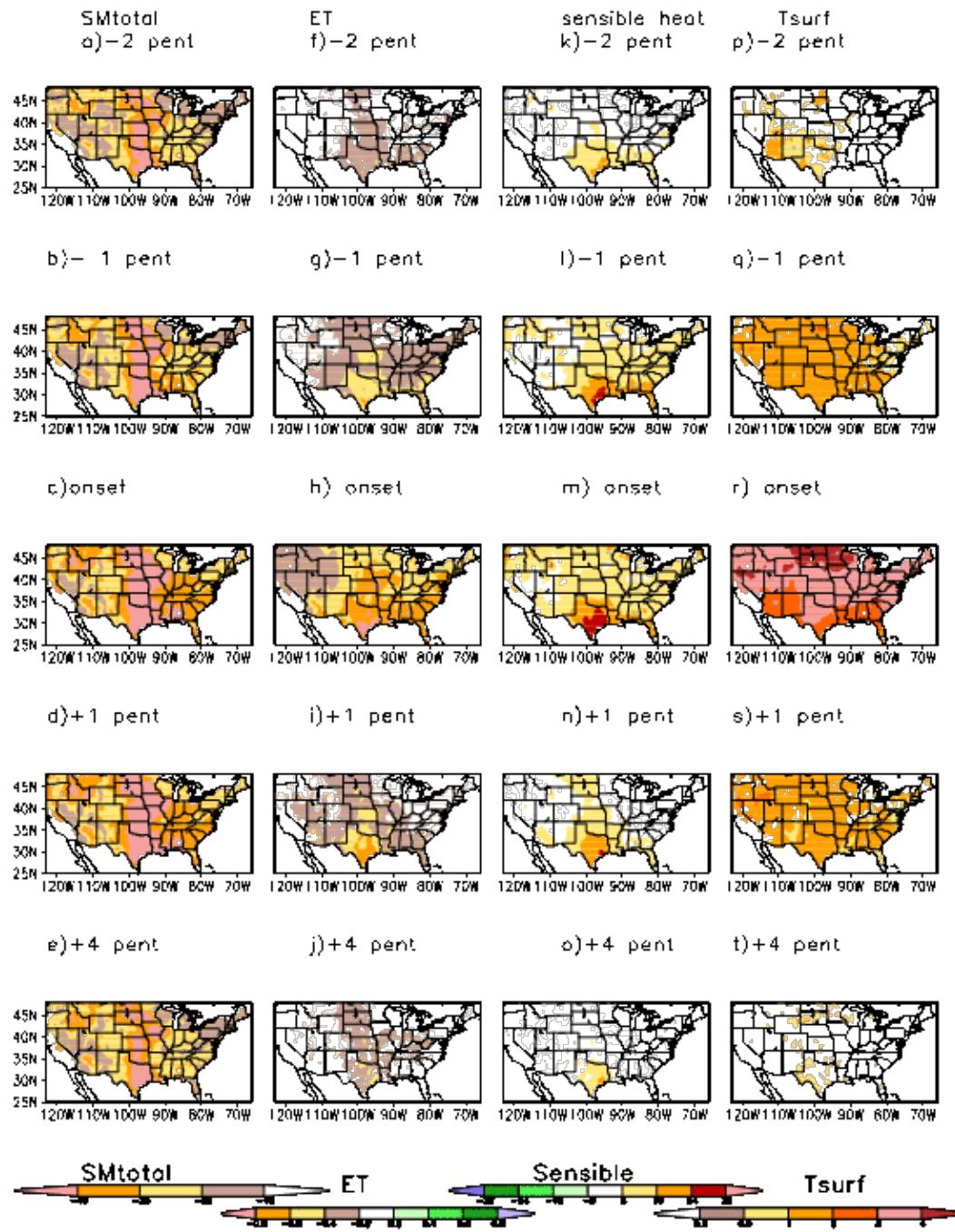
Tsurf

ET

total SM

P





## Evolution of type 2 flash drought

1. Smtotal were negative from pentad -2 to pentad +4 and beyond (*before the heat waves*)
2. ET is negative
3. Good correspondence between ET=> sensible heat => Tsurf
3. Heat waves again do not persist, but SM does

If there were no P deficits, will there be heat waves?

# Experiment

## Objective:

To isolate influence on SM by Temperature and P forcings

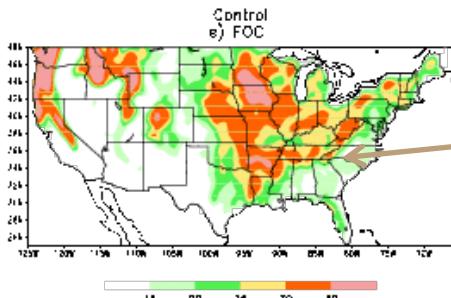
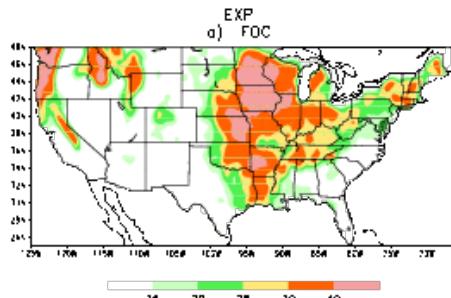
## Setup

- VIC model : water balance model 4.0.6
- VIC(SIM) driven by observed P, Tmax, Tmin and surface wind speed
- VIC experiments: same model, same initial conditions and same T and wind forcing.
- the daily **observed** P is replaced by daily P **climatology** from the period 1979-2011

The experiment was run from 1jan1979-31dec2011 and processed data the same way as before

Exp

control



# of events: similar

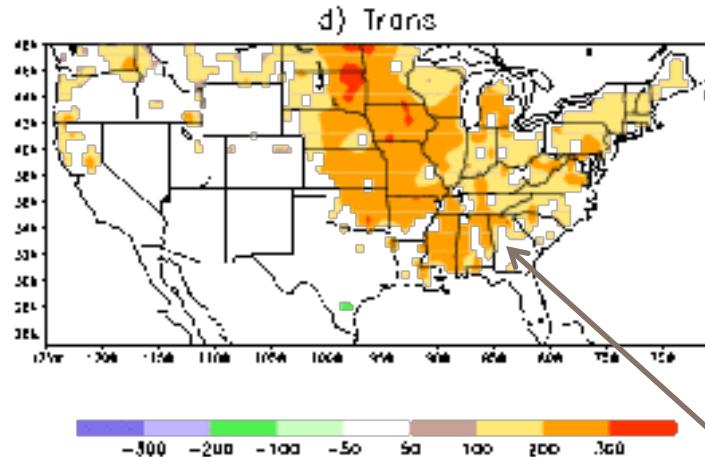
P: control has more SM depletion than exp

ET both positive, magnitudes are similar

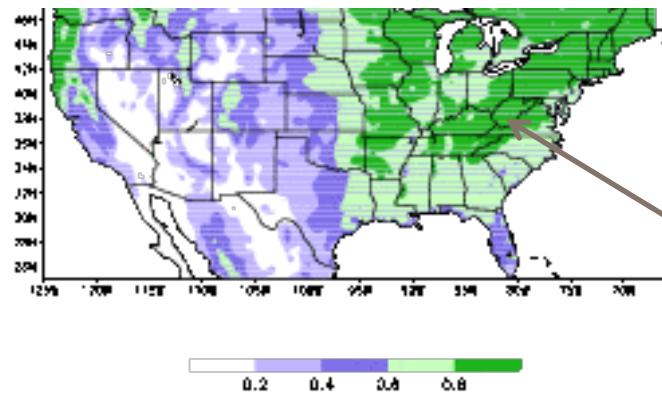
Tsurf : both about 3-4C above normal

# Type 1

Composite of transpiration



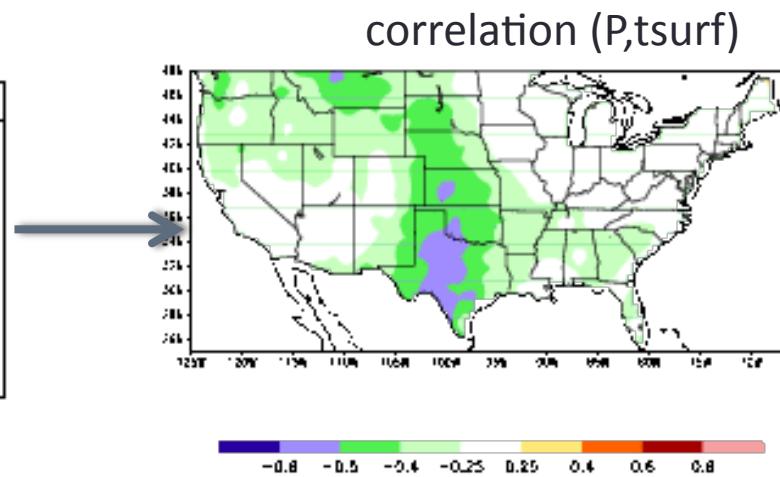
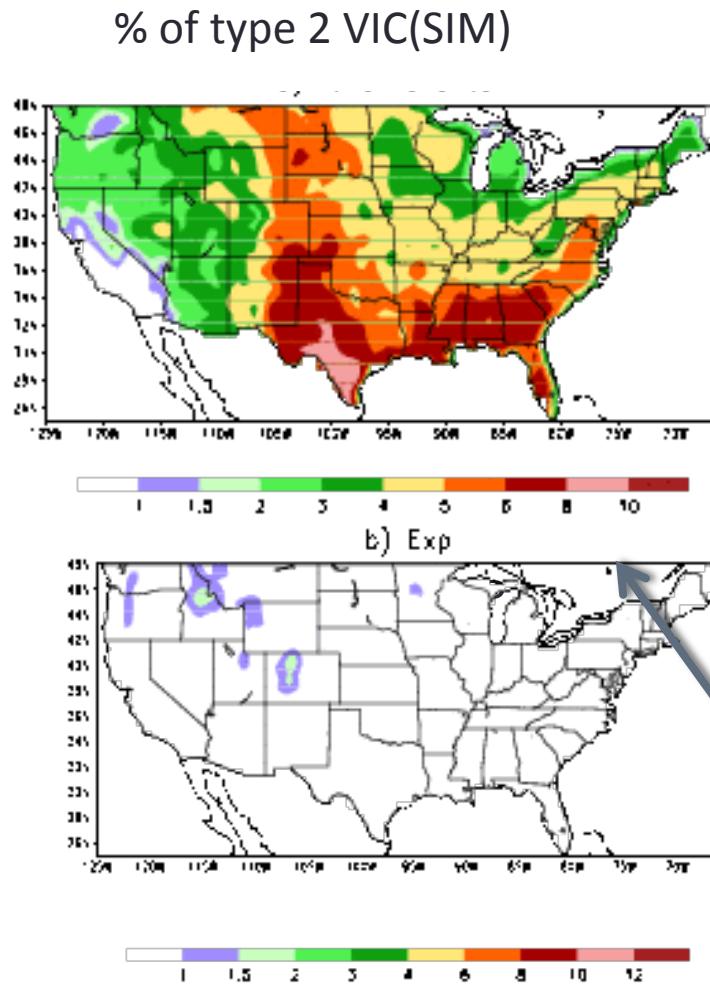
Vegetation fraction JJA



From experiment:

- The type 1 flash drought is a temperature driven event.
- High temperatures lead to the increases of ET and the decreases of SM;
- P can deepen the SM depletion and enhance the impact, but events will occur wt P
- The increases of ET come from **transpiration**, so type 1 flash drought can only occur in the **vegetation dense** areas.

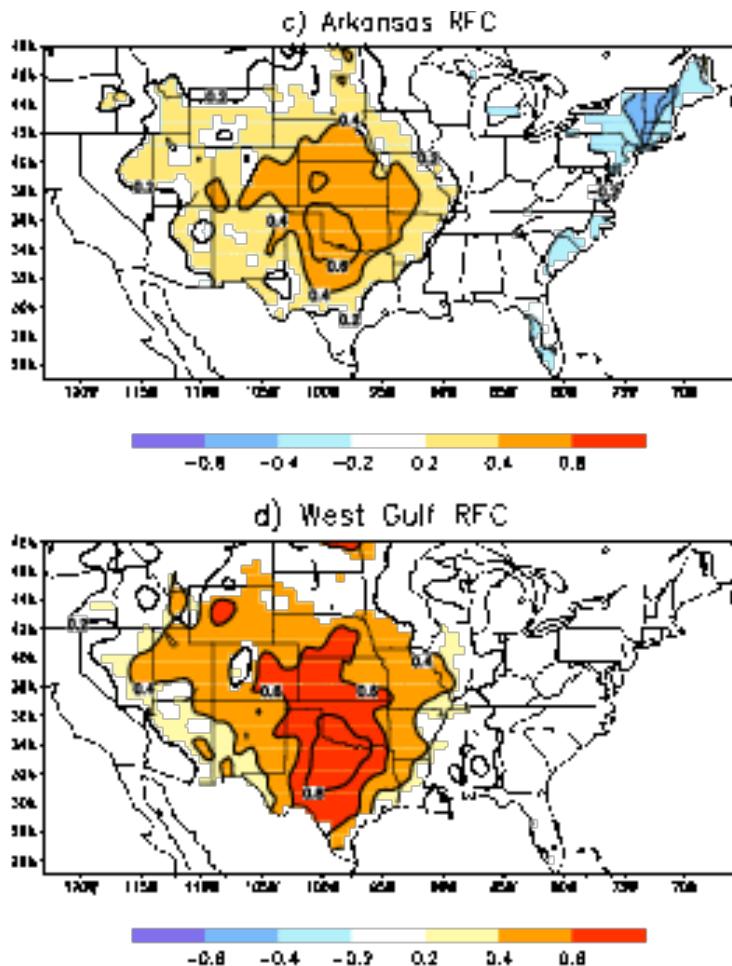
# Type 2 flash drought is P driven



Type 2 events in the areas where  $\text{corr}(P,T)$  is strongest

No P anomalies=> no type 2 flash drought  
It occurs in the areas where the land-atmosphere interactions are strong

# Does meteorological drought over the type 2 areas lead to heat waves?



1. We picked two RFC areas over the Southern Plains
2. We select drought events when SPI6 is below -0.8 for 6 months or longer
3. Sum up Tsurf anom over drought periods
4. Composites show that heat waves are likely to occur during drought

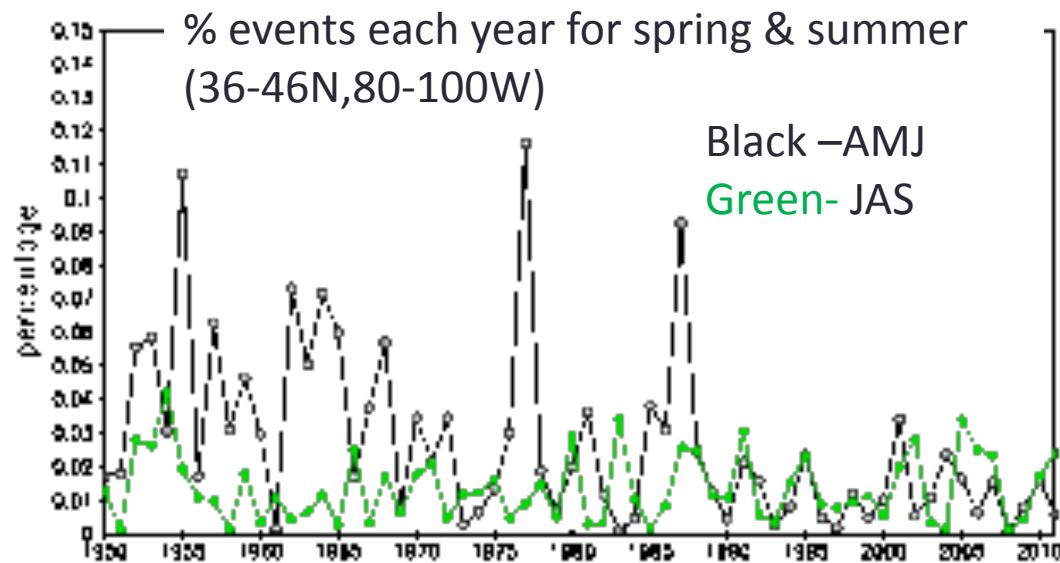
( The lack of P will increase surface temperature and lead to heat waves)

# Conclusions

- There are two types of flash drought over the United States
- Both indicate: High temperatures and depletion of SM
- **Type 1 :**  $ET > 0$  and is temperature driven
- Preferred areas have dense vegetation
- High  $T_{surf} \Rightarrow$  increases of transpiration  $\Rightarrow$  decreases of SM
- P deficits will enhance the impact.
- It is not related to meteorological drought
- **Type 2:**  $ET < 0$  precipitation driven
- Preferred area has strong correlation between P and  $T_{surf}$
- P deficits  $\Rightarrow$  decreases of ET  $\Rightarrow$  increases of sensible heat  $\Rightarrow$  high  $T_{surf}$
- It likes to occur during meteorological drought
- .

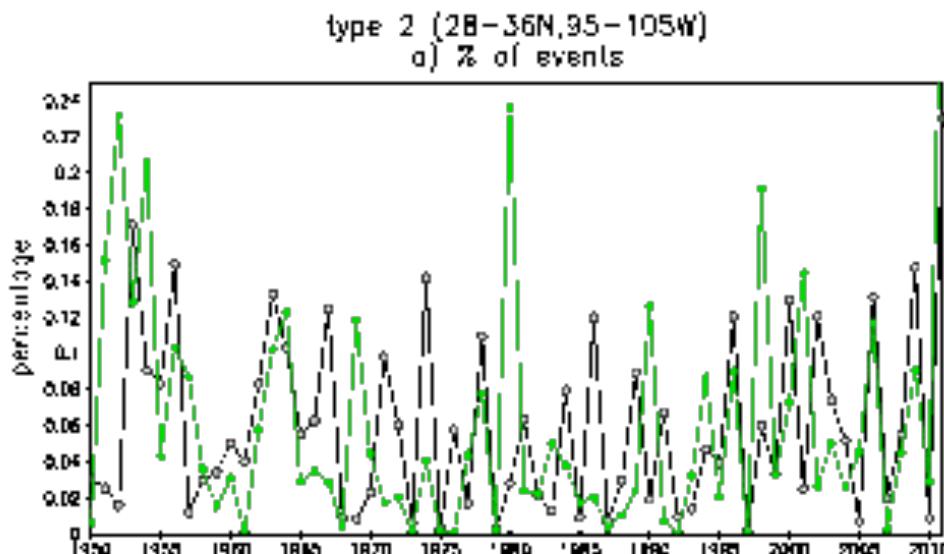
# Seasonal distribution

Type 1



Type 1 is more like to occur in spring

Type 2

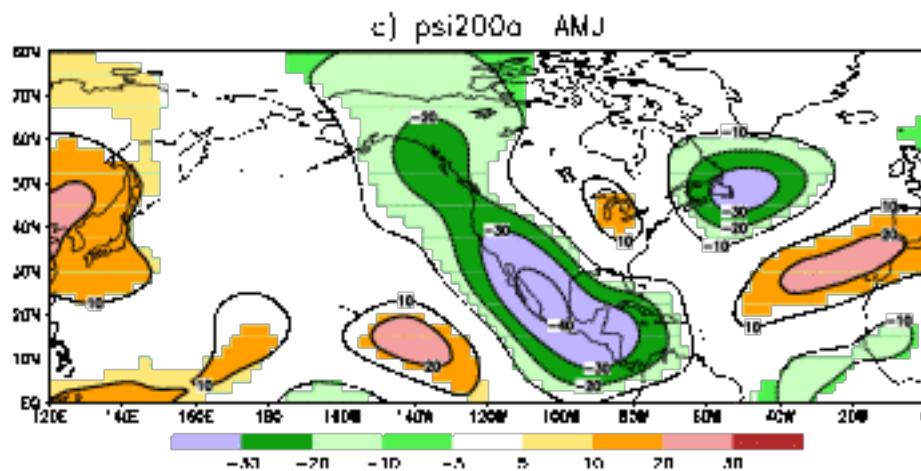
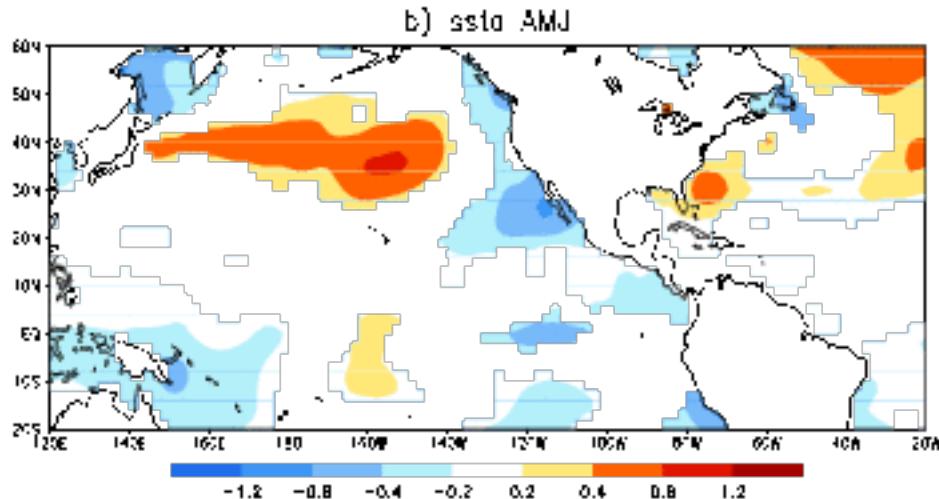


Type 2 no preference

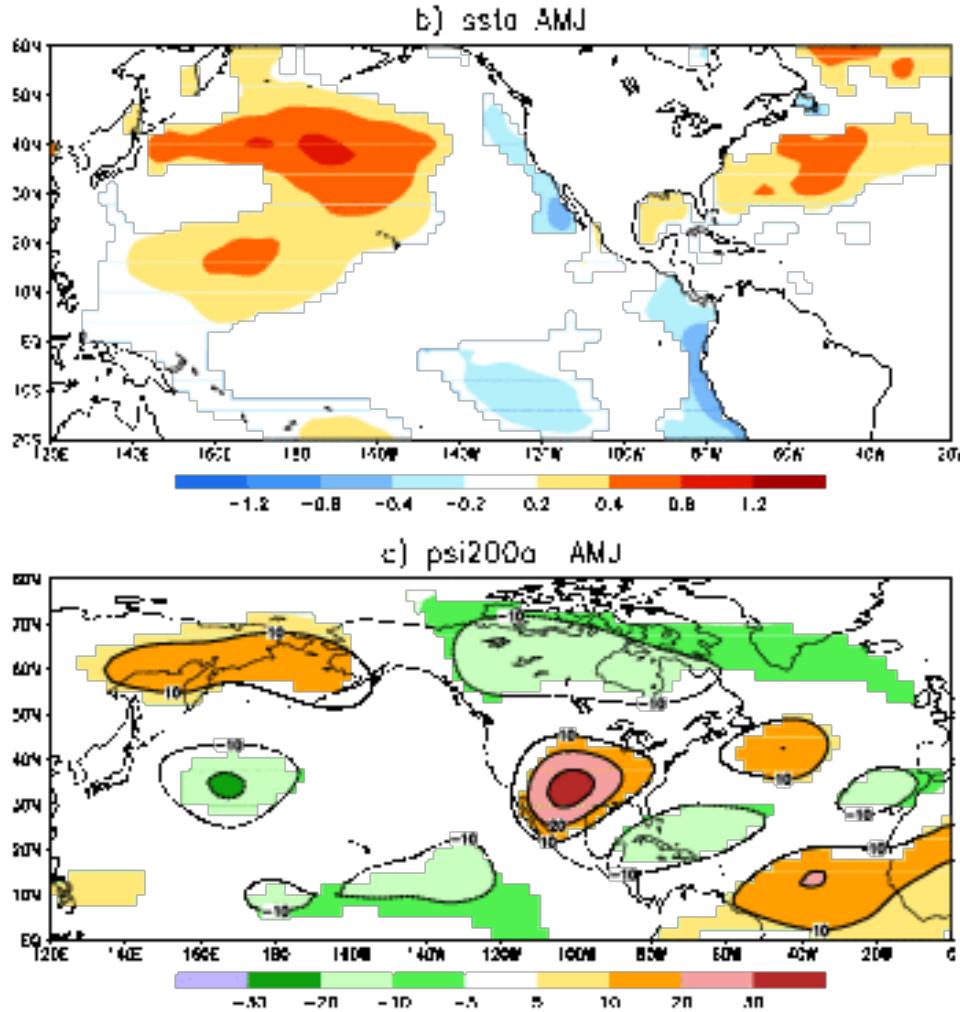
# Attribution type 1

Type 1 SST and 200 hPa  
streamfn anomaly composites  
For 10 max events years (slide  
14)

Positive SSTAs anomalies in  
the North Pacific  
The associated 200 hPa  
streamfn anomalies show  
an anti cyclone over the  
North Central – The area of  
the maximum occurrence



# Attribution type 2



Composites for type 2

Positive SSTAs in the North Pacific and warm SSTAs in the North Atlantic

Composite of 200 stramfn indicates an anti cyclone located over the Southern Plains